REMARKS

Claims 1-13, 15-29 and 32-35 are pending in this application. Claims 30 and 31 have been canceled and claim 19 has been amended to incorporate the limitations of former claim 30. Claim 1 has been amended to specify that tungsten cap layer that terminates the stack reduces roughness of the tungsten film stack. Support for this amendment may be found at (page 16, lines 3-4). No new matter has been added.

Applicants' representatives thank the Examiner for the courtesy of the telephonic interview on August 30, 2005. During the interview, the rejections of claims 1 and 19 were discussed. The amendments and accompanying arguments presented below were discussed. Although no agreement was reached, the Examiner indicated that the amendments would be considered. The Examiner also requested that the Applicants include the specific positions discussed during the interview in this response. This has been done. The undersigned welcomes any further discussion that the Examiner believes appropriate after reviewing this response.

Rejections Under 35 U.S.C. § 103

Claims 9-13 and 19-35 were rejected under 35 U.S.C § 103(a) as being unpatentable over Chang et al. U.S. Patent No. 5,028,565 ("Chang") in view of Klaus et al. "Atomically controlled growth of tungsten and tungsten nitride using sequential service reactions" ("Klaus"). Claims 1-8 and 14-18 were rejected under 35 U.S.C § 103(a) as being unpatentable over Chang in view of Klaus and further in view of either Sukharev et al. U.S. Patent No. 5,804,249 ("Sukharev") or Berenbaum et al. U.S. Patent No. 6,066,366 ("Berenbaum"). Applicants respectfully submit that the claims as currently presented are patentable over the cited art.

Claims 19-35

Claim 19 as amended is directed toward a pulsed tungsten deposition process wherein tungsten layers are formed by contacting a layer of reducing agent formed on the substrate with a tungsten-containing gas. Importantly, the process uses two different reducing agent layers: a boron layer in an initial tungsten deposition cycle (steps (a) and (b)) and a silane layer in a subsequent tungsten deposition cycle (steps (c) and (d)). This aspect of Applicants' invention results in the particular benefits of using a boron layer for an initial deposition cycle and using a silane-based reaction for a subsequent cycle. Specifically, the initial boron layer reduces the

sensitivity of the deposition process to variations in the incoming semiconductor wafers. In one embodiment, one can even nucleate tungsten on wafer surfaces with discontinuous Ti-TiN line-barrier films (page 18, lines 6-8). Using silane for subsequent deposition processes is advantageous in many embodiments because it can fully saturate any topography given sufficient dose times and improve step coverage (page 18, lines 15-18). Thus, Applicants' method results in the advantages of using an initial boron layer (e.g., reduced sensitivity to wafer variations) as well as the advantages of using silane after the initial tungsten layer is deposited (e.g., improved step coverage).

None of the cited references, either alone or in combination, teach or suggest forming an initial boron layer on the substrate and forming a silane layer in subsequent deposition cycles. Chang teaches a CVD process which deposits a film after a vapor-phase reaction using hydrogen gas as reducing agent. Klaus teaches a conventional ALD method of deposition tungsten using silane as a reducing agent. Neither of these references teach or suggest forming an initial boron layer on the substrate, and using a different reducing agent in subsequent steps. Further, US Patent No. 6,107,200 to Takagi ("Takagi"), supplied by the Examiner to show the equivalence of diborane and silane reducing agents, does not teach or suggest forming an initial boron layer on the substrate or using silane in subsequent steps.[1]

In addition to being patentable for the reasons given above with respect to claim 19, features of the dependent claims are independently patentable over the cited art. For example, claim 20 is specifies that forming the boron layer comprises decomposing a borane compound on the substrate. Unlike silane-based reactions in conventional ALD processes (such as those taught in Klaus), boron deposition is not typically self-limiting but decomposes thermally to produce a boron film under typical PNL operating conditions (page 17, lines 12-16). In some embodiments, due to the particular kinetics of boron growth, a very thin boron film can be deposited as a sacrificial layer (page 18, lines 1-3). Neither Chang nor Klaus teach decomposing a borane compound on a substrate.

At least for these reasons, Applicants submit that claims 19-35 are patentable over the cited art and request that the Examiner withdraw these 35 U.S.C § 103(a) rejections.

[1] The Examiner also cited Elers et al. WO 01/273447 to show the equivalence of diborane and silane as reducing agents; however Applicants were unable to find a patent publication having that number.

Claims 1-8

Claims 1-8 are directed toward a tungsten deposition process wherein three distinct tungsten layers are deposited on a substrate: a tungsten nucleation layer, a tungsten bulk layer on the nucleation layer deposited by a CVD process; and a tungsten cap layer on the tungsten bulk layer deposited by a PNL deposition technique, wherein a tungsten cap layer terminates the stack. As amended, claim 1 specifies that the terminal cap layer reduces the roughness the resulting film stack.

The Examiner contends that one of ordinary skill in the art would be motivated to modify Klaus and Chang with Sukharev to adjust the deposition of and optimize the smoothness of the tungsten layers. Applicants submit that one would not be motivated to modify the Klaus and Chang with Sukharev to arrive at the invention as described by claim 1 as amended because none of the references teach or suggest a tungsten film stack having a CVD bulk layer and terminated by a cap layer that reduces the roughness of the stack.

Sukharev discloses a process of forming a tungsten contact plug on an IC. The process involves depositing a first bulk layer, depositing an amorphous layer on the bulk layer and the second bulk layer on the amorphous layer. A discussed purpose of the amorphous layer is to create nucleation centers for deposition of the second bulk layer (col. 2, lines 51-57; col. 7, lines 30-32). Sukharev discloses that multiple layers may be deposited, however in the disclosed embodiments the film stack always terminates with a bulk layer (col. 7, lines 59-65). Contrary to the Examiner's contention, there is no teaching or suggestion that the amorphous layer could terminate the stack.

As noted above, Applicants' method requires a terminal cap layer deposited on the CVD bulk layer. As the method of Sukharev teaches that a bulk layer terminates the stack, there is no teaching or suggestion in Sukharev of such a terminal cap layer deposited on the bulk layer.

Because none of the cited references a tungsten film stack having a CVD bulk layer and terminated by a cap layer that reduces the roughness of the stack, Applicants submit that claims 1-8 are patentable over the cited art and request that the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Claims 9-13 and 15-18

Claim 9 is directed to depositing a tungsten nucleation layer and a tungsten bulk layer in the presence of nitrogen. As discussed in Applicants' April 2005 Amendment, in depositing the tungsten nucleation layer, exposure of the substrate to nitrogen is delayed until after deposition of the tungsten nucleation layer has begun.

The Examiner acknowledges that Chang and Klaus, either alone or in combination, do not teach or suggest delaying the nitrogen exposure, but relies upon Berenbaum to supply this element. Applicants submit the one of skill in the art would not be motivated to delay nitrogen exposure during nucleation, as claim 9 requires, because Berenbaum teaches away from such a delay.

As discussed in the April 2005 Amendment, Berenbaum teaches depositing tungsten layers by CVD by a method having 3 steps: a nucleation step, an inter-deposition step, and a main deposition step. Specifically, experiments 1-4 in Figure 1 of Berenbaum show the results of nitrogen exposure during various stages of the nucleation step including no nitrogen exposure, nitrogen exposure only at the beginning of the nucleation step and delayed exposure. Delaying nitrogen exposure (Experiment 4) resulted in instability. Stable growth was achieved only with no nitrogen (Experiment 2) or nitrogen present only at the onset of the nucleation step (Experiment 3). Because Berenbaum teaches that delaying nitrogen exposure results in instability, one of skill in the art would have no motivation to modify the processes of Chang and/or Klaus as the Examiner suggests.

For at least the reasons given above, claim 9 as amended is patentable over the cited art. Pending depending claims 10-13 and 15-18 are also patentable for at least these reasons. Accordingly, Applicants request the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Applicants note that the above arguments relating to claims 9-13 and 15-18 were presented in the April 2005 Amendment do not appear to be addressed in the Final Office Action. Applicants respectfully request consideration of these arguments.

Conclusion:

In light of the foregoing amendments and remarks, Applicants respectfully submit that all pending claims are now in condition for allowance. Thus, Applicants respectfully request a Notice of Allowance from the Examiner. Should any unresolved issues remain, the Examiner is encouraged to contact the undersigned at the telephone number provided below. If the Commissioner determines that any fee is due that is not herewith submitted, such fee may be charged to deposit account No. 500388 (Order No. NOVLP033X1).

Respectfully submitted,
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